DEVILS ON THE DARLING DOWNS — THE TOOTH MARK RECORD

Ian H. Sobbe

Sobbe, Ian H. 1990 00 00: Devils on the Darling Downs — the Tooth Mark Record. *Mem. Qd Mus.* 27(2): 299-322. Brisbane. ISSN 0079-8835.

Fossil bones collected from Pleistocene deposits of the eastern Darling Downs show a variety of marks, many of which are considered to be the tooth marks of carnivores. A feeding trial was conducted to identify those tooth marks that might have been produced by the Tasmanian Devil (*Sarcophilus harrisii*), the largest extant marsupial carnivore known to have inhabited the Darling Downs. Fifteen categories of tooth marks are described: ten from the fossil sample and five from the feeding trial. A clear overlap exists between some categories of fossil tooth marks and those produced in the feeding trial. From the existing fossil evidence, *Sarcophilus* appears to have been a major carnivore on the eastern Darling Downs in the late Pleistocene.
☐ *Darling Downs, Pleistocene, taphonomy, tooth marks, Sarcophilus, Thylacoleo.*

Ian H. Sobbe, M/S 422, Clifton, Queensland, 4361, Australia;

Recent collecting on the Darling Downs, southeastern Queensland, has yielded a large number of fossil bones which may record the feeding activities of Pleistocene predators and scavengers.

In times of diminished food supply, all carcasses would be consumed by predators and the remnant bones consumed by scavengers such as *Sarcophilus* and most likely *Megalania*. However, in periods of abundant food supply, some carcass remnants will remain unconsumed. Some of these unconsumed bones will bear the tooth marks of the predatory and scavenging animals and will then survive to be preserved as fossils.

Marks on Australian fossil marsupial bones have been recorded by many other workers including de Vis (1900), Spencer and Walcott (1911), Douglas *et al.* (1966), Archer *et al.* (1980), Horton and Wright (1981) and Runnegar (1983). Many of these descriptions placed little emphasis on microscopic examination of the marks or on comparison with marks known to have been made by specific predators or scavengers. One of the problems encountered in this area of research is that some of the animals potentially responsible for tooth marks are extinct and have left no direct descendants that might furnish comparative data.

The major predators and scavengers recorded from Pleistocene sites of southeastern Queensland are: Muridae, (*Rattus* sp.); Thylacinidae, (*Thylacinus* sp.); Dasyuridae, (*Dasyurus* sp., *Sarcophilus* sp.); Thylacoleonidae, (*Thylacoleo* sp.); Varanidae, (*Varanus* sp., *Megalania* sp.); and Crocodylidae, (*Crocodylus* sp.) (Bartholomai, 1976; Molnar, 1982; Archer *et al.*, 1984).

The largest extant marsupial carnivore in this list is the Tasmanian Devil (*Sarcophilus harrisii*). In this study I have concentrated on *Sarcophilus* in an attempt to recognise marks left on bone during its feeding activity. *Sarcophilus* is known to eat bone as part of its normal diet and has the potential to produce a range of tooth marks on the bones of its prey. Captive devils are common in zoological gardens and are good subjects for a feeding trial. A feeding trial was conducted at Lone Pine Koala Sanctuary, Brisbane, to determine the nature and extent of tooth marks on bones chewed by *Sarcophilus*. The resulting tooth marks were then

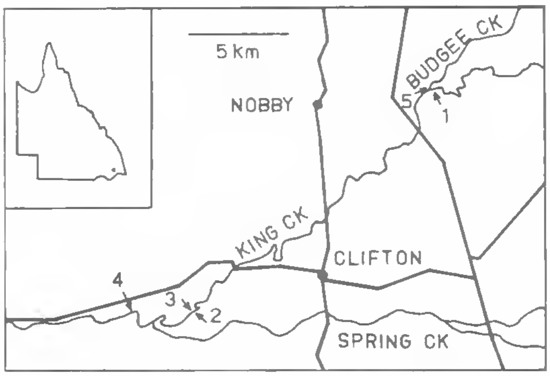

FIG. 1. Map of the King Creek area showing collecting sites.

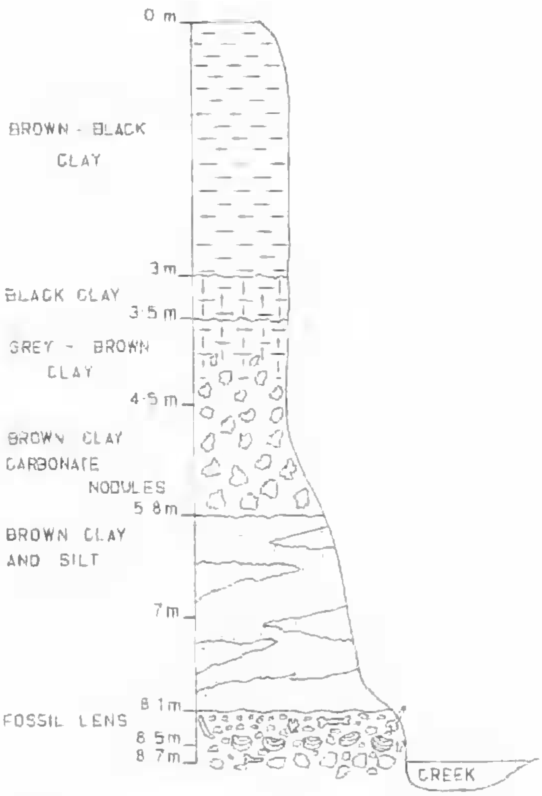

FIG. 2. Stratigraphic section of south bank of King Creek at GR 858079 (Locality 2 of this study).

compared with those on fossil bones of Pleistocene age.

REPOSITORIES

All figured specimens have been placed in the collection of the Queensland Museum. These are identified by the prefix QM. Additional bulk specimens are housed in the collection of the author.

LOCALITIES AND AGE

Fossil specimens used in this study were all derived from Pleistocene fluviatile deposits at various localities along King Creek and Budgee Creek, Darling Downs, SE Queensland (Fig. 1). Grid references for these localities are: (1) King Creek, S bank, between 976193 and 979193; (2) King Creek, S bank, 858079; (3) King Creek, N bank, 856080; (4) King Creek, N bank, 828080; and (5) Budgee Creek, W bank, 975194 (Royal Australian Survey Corps, 1:100,000 Series Map, Toowoomba, Sheet No. 9242). These deposits are exposed by flood-water erosion in the lower portion of the creek bank. In the case of the measured section described below, fossils are accessible to a depth of 8.7 m (Fig. 2). This does not represent the base of the fossil deposits but simply water level as at August, 1988, and thus the approximate limit of available *in situ* collecting.

Associated charcoal and carbonate nodules from site (2) were dated by Gill and MacIntosh and recorded in Gill (1978) and Baird (1985). Dates are: Charcoal 23,600 ± 600 B.P. (N.Z. 612), 28,400 ± 1,400 B.P. (JAK 1394), 41,500 ± 6,100 B.P. (N.Z. 613); and Carbonate 24,000 ± 600 B.P. (N.Z. 641), 30,800 ± 3,000 B.P. (N.Z. 640). These C14 dates were obtained during the late 1960's. They were used by Baird (1985) and would appear to be the only dates available for these particular beds. Further datings for the whole King Creek stratigraphic sequence would be desirable and would further refine our knowledge of the age of fossil beds in this area.

Subsequent to the dating of locality (2), erosion has lowered the water level by approximately 0.5 m — 1 m. This has allowed collecting from slightly deeper in the fluviatile lenses. The stratigraphy and major faunal elements of the various sites appear to be rather uniform, and the specimens in this study should, therefore, be of an age roughly consistent with the dates cited above.

STRATIGRAPHY

Woods (1960) and Gill (1978) have documented some aspects of the stratigraphy of the King Creek area, but their accounts show some variance from the stratigraphy at some localities considered in this paper.

The measured section (Fig. 2) of locality (2) is as follows:

0-3 m — Brown to black clay — Ellinthorpe Clay (Gill, 1978). Occasional small shelly lenses (*Plotiopsis* sp., *Corbiculina* sp.) present in some areas.

3-3.5 m — Deep black clay. Yellow nodules (? iron) present at the lower limit of this soil unit.

3.5-4.5 m — A transitional unit grading from grey clay above through to brown clay with occasional carbonate nodules below.

4.5-5.8 m — Brown clay with extensive carbonate in the form of irregular nodules and crack infillings. — Talgai Pedoderm (Gill, 1978).
5.8-8.1 m — Brown clay with silt lenses containing numerous shells (*Plotiopsis* sp., *Corbiculina* sp.) and some fossil bones — Toolburra Silt (Gill, 1978). The bones are often heavily encrusted with carbonate. In some areas adjacent to the measured section these fossil lenses are continuous up to a level of 7 m. In other parts of King Creek (locality (1) of this study) numerous fossil bones are found throughout this unit
8.1-8.5 m — Nodular lens containing fossil bones. Silt matrix containing numerous waterworn calcareous nodules (maximum size 4 cm). Some well-rounded stones (size up to 1.25 cm, and occasionally to 2.5 cm) and numerous shells. (*Plotiopsis* sp., *Corbiculina* sp., *Velesunio* sp.).
8.5 m — Layer within nodular lens with abundant *Velesunio* sp. shells.
8.5-8.7 m — Continuation of nodular lens containing fossil bones. Similar to the upper portion of the lens except that calcareous nodules (maximum size 7.5 cm) and stones (maximum size 4-5 cm) are generally of larger size.
8.7 m — Creek water level (August, 1988). The nodular lens continues below this level; maximum depth not known.

The stratigraphy of other parts of King Creek differs in some details from the described section. Localities closer to the headwaters of King Creek (e.g. locality (1) of this study) have some stones of larger size (up to approximately 10 cm) in the lower beds. Fossils are rarer and generally fragmentary in these stony beds.

METHODS

More than 100 tooth-marked bones have been collected in the last three years. These range from complete, or near-complete, elements through to unidentifiable fragments with a diameter of 1 cm. Two methods of collection were employed, viz.: systematic collecting of all fossil bones exposed in the creek bank after heavy rainfall and/or flooding; and digging and collection of all fossil bones from selected areas of the creek bank. Most specimens were recovered by the former method.

As all but the most obvious marks are difficult to see, careful cleaning of the specimens is required. First the bones were soaked in water to soften adhering clays, then lightly brushed with a soft nylon bristle brush. Cleaned specimens were checked for marks under sunlight or an incandescent bulb as fluorescent and other diffuse light sources do not produce shadows to highlight the contour of individual marks.

Marks on fossil bones and those from the feeding trial were examined using low magnification microscopy, 35 mm S.L.R. photography, and scanning electron microscopy. Most bones were too big to be examined directly, thus areas of interest were replicated in clear resin for close examination. Rose (1983) provides details of this technique.

DESCRIPTION OF FOSSIL MARKS

Many bones show various degrees of damage due to fluvial, geophysical and chemical factors:

- exfoliation and cracking of the bone surface due to exposure before fossilization (see Behrensmeyer, 1978);
- breakage, abrasion and rounding of the bone surface due to rolling in stream sediments (see Shipman & Rose, 1983);
- breakage due to shrinkage and swelling of the enclosing clays (see Wood & Johnson, 1978);
- pitting of the surface by the action of acidic ground waters and possibly corrosion by plant roots (see Archer *et al.*, 1980);
- breakage and marks accidentally inflicted during excavation. These areas show a distinctly different colour to the remainder of the specimen, and, therefore, are readily identifiable.

Some bones have a series of marks which are not attributable to any of the aforementioned factors. These are interpreted as tooth marks of scavengers or predators, because they take the form of pits, scratches, punctures and blade-like incisions in the bone surface. Such marks have been identified as typical of the damage inflicted to bone by a variety of carnivores (see Haynes, 1983). In addition, the marks often occur as pairs on the opposite sides of single bones; these paired markings presumably correspond to teeth in the opposing jaws of carnivores.

Gill (pers. comm., 1986) suggested that many of the marks, particularly those described here as blade-like impressions, could be the result of aboriginal butchering of carcasses using stone tools. Such butchery would presumably involve separation of the carcass into portions small enough for easy transportation, cooking or eating. The easiest way to dismember a carcass is to separate it at the major joints by severing the attaching flesh and tendons. This process would tend to mark the bones mainly in the area of the major joint tendons, close to the ends of long bones.

In fact, marks are widely distributed on the fossil bones and are not concentrated around the joints. Several paired marks are recorded on a macropod distal phalanx. This, however, would be an unlikely site for butchery marks. Moreover, butchery would be expected to produce a random orientation of marks and not consistent pairing.

Recognition and definition of Man-made marks on bone are discussed by Potts and Shipman (1981) and by Shipman and Rose (1983a, b). The marks include those produced by slicing, chopping and scraping. Slicing marks are "elongate grooves, containing within its edges, multiple fine parallel striations orientated longitudinally" (Shipman & Rose, 1983a). Such fine parallel striations have not been observed in this study. Chopping marks are V-shaped in cross section, as are the marks produced by the sectorial premolars of *Thylacoleo* sp. (Horton & Wright, 1981). The fact that the marks seen on the Darling Downs specimens generally occur as opposed pairs would seem to implicate *Thylacoleo;* examples are described below.

Fossils have been collected from eastern Darling Downs for more than 140 years (Bartholomai, 1976), and in that time not one artifact has been found in the beds containing fossil marsupial bones. By contrast, numerous artifacts are found in surface or near-surface deposits. Thus, it would appear that aboriginal butchery is unlikely to be the cause of the marks in this study.

The tooth marks are divided into ten categories (designated A-J) discussed below. Referred specimens are described in Appendix 1. Some specimens show two or more categories of tooth marks. These associations might result from the different teeth (e.g. incisors and carnassials) of a single carnivore, from juvenile and adult animals chewing on a single bone, or from more than one species of carnivore.

Exact counts of marked bones in individual collections have yet to be compiled. However, washed bones were sorted into marked and nonmarked groups which showed frequencies of marked bones in the range of 10-50%.

Some marks are rare whereas others are present on a large number of specimens, some of which show moderate to severe weathering and breakage. The following descriptions of tooth marks are based on those specimens which show least weathering and breakage.

CATEGORIES

(A) ROUND-BOTTOMED SCRATCHES WITH ANCHOR POINTS

A series of shallow, closely-spaced, near-parallel scratches that taper slightly present on one surface of several specimens (Fig. 3). Length 3-7 mm; Width 0.3 — 0.6 mm; Depth approximately 0.25-0.5 mm. Immediately above the broader end of the scratches is a series of shallow, near-circular pits, 0.4-0.6 mm in diameter, which appear to be tooth anchor points (Fig. 3A, C). In some areas the scratches are so frequent and closely-spaced as to remove complete areas of the bone surface (Fig. 3B).

Rodents chew by anchoring their upper incisors and drawing the lower incisors upwards. At times only one lower incisor is in contact with the surface being chewed, thus producing a single tooth mark (Archer *et al.,* 1980). This action would produce marks similar to those described from the fossil specimens, which also resemble the murid gnawings described by Archer *et al.* (1980) and by Shipman and Rose (1983).

(B) BLADE-LIKE IMPRESSIONS

Long blade-like impressions on opposing bone surfaces are present on a considerable number of specimens. The marks are V-shaped in cross section, and about 1 mm deep. One side of the "V" is quite flat, terminating sharply at the base, whereas the other side is rather chipped (Fig. 4). In the case of paired marks, the flat sides of the marks oppose each other (Fig. 5). The maximum length is not known since the marks extend fully across many specimens. The longest recorded mark is approximately 27 mm, present on the edge of a fragment of macropod pelvis, apparently sheared in two by a bite at the level of the acetabulum (Fig. 4C). These pairs of opposing marks subtend an angle in the range of 18°-28°. They appear to be formed by a pair of large blade-like teeth, probably *Thylacoleo* premolars. Similar marks have been attributed to *Thylacoleo* by other workers including de Vis (1900) and Horton and Wright (1981).

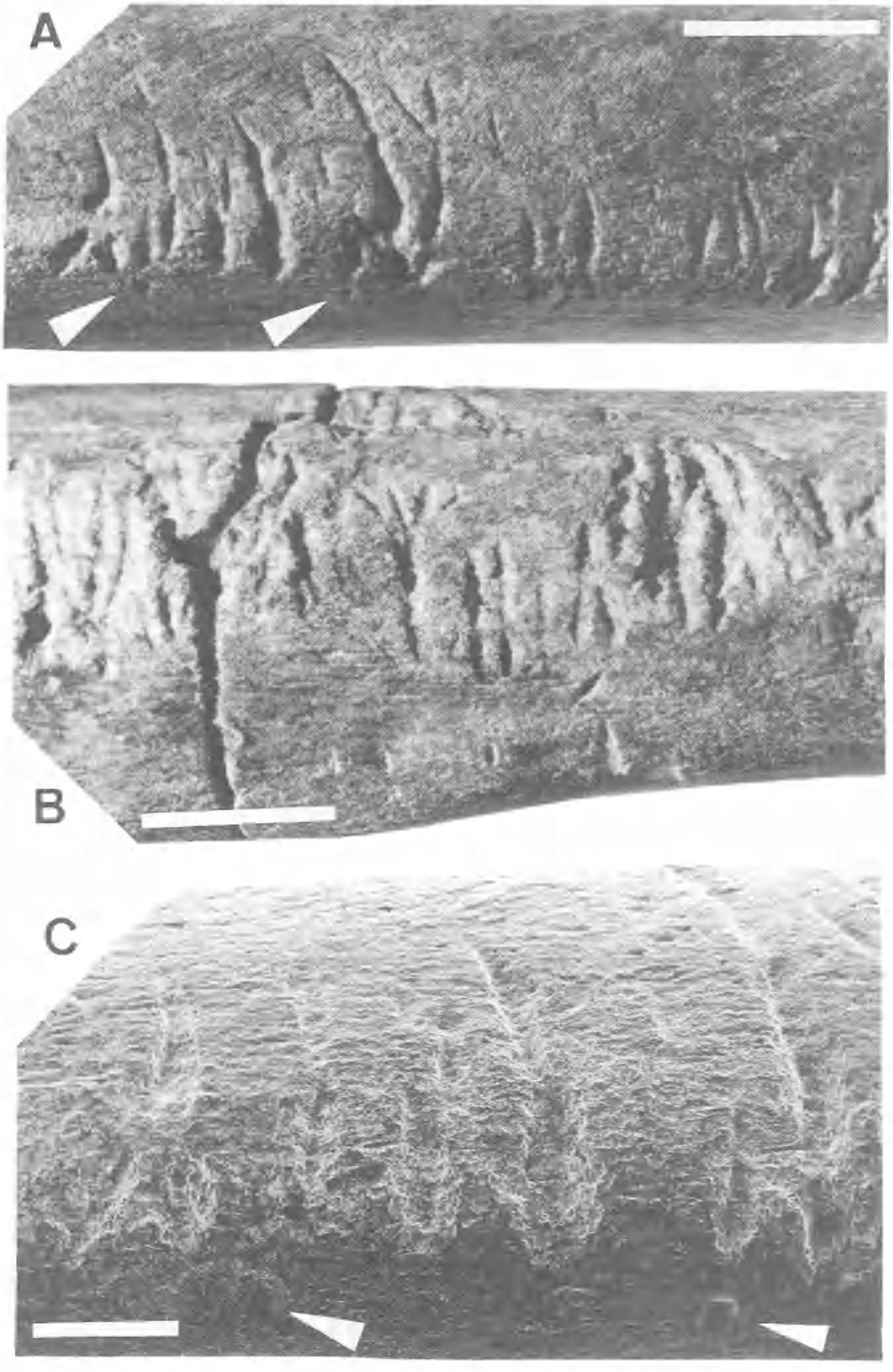

FIG. 3. CATEGORY A — Round Bottomed Scratches with Anchor Points
A Macropod rib (QM F14504) showing shallow, closely spaced, tapering scratches with anchor points (Arrowed).
B Closely spaced scratches resulting in complete removal of bone surface (QM F14504).
C Scanning Electron Micrograph showing detailed shape of marks (QM F14504).
Scale: A and B Scale Bar = 5 mm. C Scale Bar = 1 mm

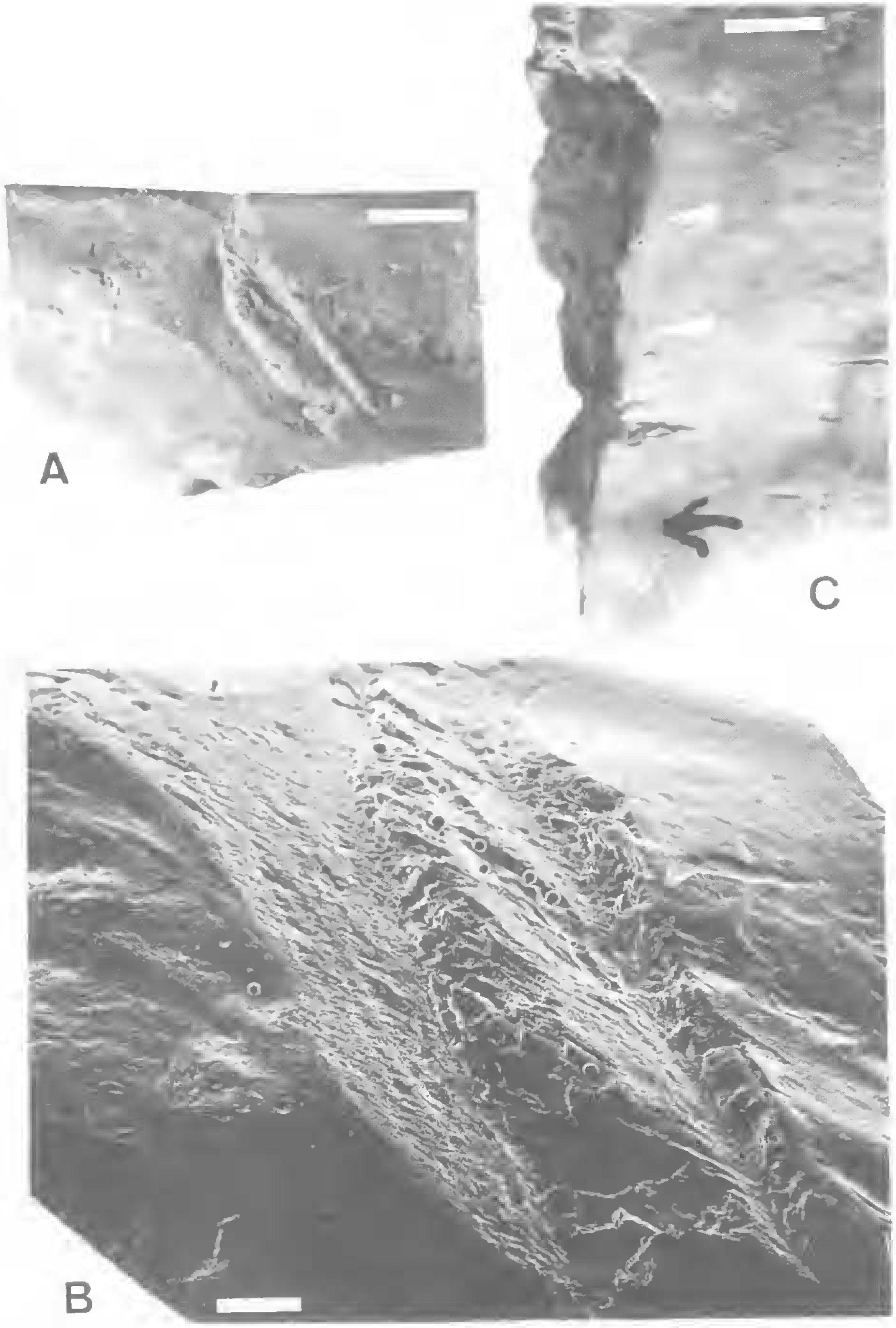

FIG. 4. CATEGORY B — Blade-Like Impressions
A Macropod rib (QM F14505) showing blade like impressions with V shaped cross section.
B Scanning Electron Micrograph of QM F14505 showing details of flat and chipped sides of V shaped mark. The dark spheres in this and subsequent SEM's are air bubbles trapped during casting procedures.
C Macropod pelvis (QM F14506) apparently sheared in two by a single bite — Note bite facet (arrowed).
Scale: A and C Scale Bar = 5 mm. B Scale Bar = 1 mm.

If these marks are sufficiently deep to break through the compact bone (3 mm on one specimen), they assume a different round-bottomed shape in the spongy bone (Fig. 6A). It is only possible to see that these are an extension of the V-shaped marks on specimens where a complete gradation of marks exists.

(C) CRESCENT-SHAPED MARKS
One specimen shows three crescent shaped marks 4-5 mm wide and about 1 mm deep. The bone surface has been displaced at right angles to the long axis of the mark to leave a ridge of semi-detached bone at the concave edge (Fig. 6B).

Other marks on the same specimen are so poorly defined that they cannot be assigned to a particular category.

(D) PITS AND SCRATCHES
Many specimens bear small pits and scratches, either singly or combined in large groups, giving the bone surface a rough appearance (Fig. 7). The pits are round to oval with a diameter of up to 2 mm and depth up to 1 mm (Fig. 8). The round-bottomed scratches have parallel or slightly convergent walls and distinct basal corrugations at right angles to the long axis of the mark (Fig. 7). These corrugations, which are generally visible without magnification, show where a tooth cusp has broken through successive layers of bone tissue. Length is up to 20 mm, with most being 4-7 mm, and width up to 2 mm, with most specimens approximately 1 mm.

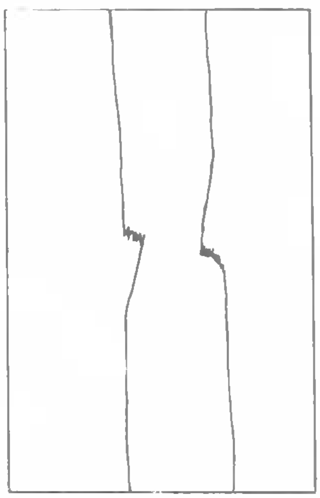

FIG. 5. Side view of paired blade like marks showing relationship to each other.

These marks are among the most numerous so far observed. Two specimens, QM F14512 and QM F14514, show boomerang-shaped marks; a shape which Horton and Wright (1981) attribute to *Thylacoleo* (Fig. 8). While such marks might well have been produced by the sectorial premolars of *Thylacoleo,* the differences in cross-sectional and basal shape indicate a different origin for QM F14512 and QM F14514.

(E) LARGE DEEP SCRATCHES

Specimen QM F14515 is a vertebra which shows a scratch mark of exceptional size. Length 27 mm; Width 5 mm; Depth approximately 2 mm. This mark shows a tapering lead into the point of greatest depth and width. From there it continues near that size for 15 mm where it strikes a large depression in the vertebra (Fig. 9A, B). A round impact point 2 mm in diameter is formed from which the mark continues at much shallower depth (approximately 0.25 mm). The initial lead in, point of greatest depth, and secondary impact suggest formation by a conical tooth under great pressure.

Three blade-like marks (Category B) and other smaller pits and scratches (Category D) are also present on the specimen.

(F) FINE SCRATCHES TAPERED AT BOTH ENDS
Several fine, round-bottomed scratches, having their widest point near the middle, and tapering markedly towards both ends, are present on specimen QM F14516. Length is 13 mm and width 0.25-0.75 mm (Fig. 9C). Transverse basal corrugations are visible under low magnification. Superficially these marks resemble those in Category (D), but sufficient differences exist to warrant separation, at least initially. Other parts of the specimen show marks assigned to Categories (D) and (J).

(G) ROUND PUNCTURES
Three round punctures of 3-3.5 mm diameter and 3-5 mm depth penetrate the compact bone

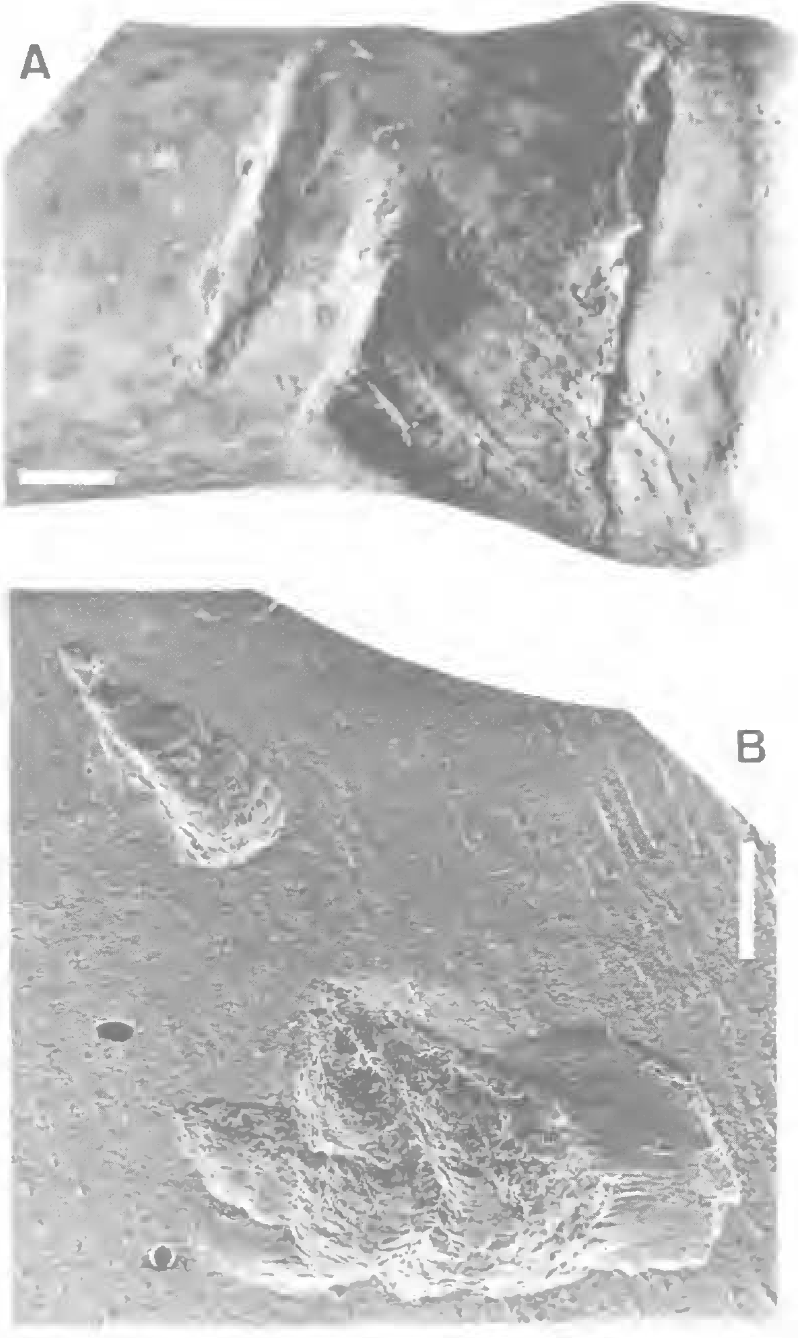

FIG. 6. CATEGORY B — Blade-Like Impressions
A Macropod radius (QM F14507) showing a gradation of marks from shallow V-shaped marks through t o deep round bottomed marks.
CATEGORY C — Crescent Shaped Marks
B Bone fragment with 3 crescent shaped marks. Note the ridge of semi-detached bone at the concave edge of the single mark.
Scale: A Scale Bar = 5 mm. B Scale Bar = 1 mm.

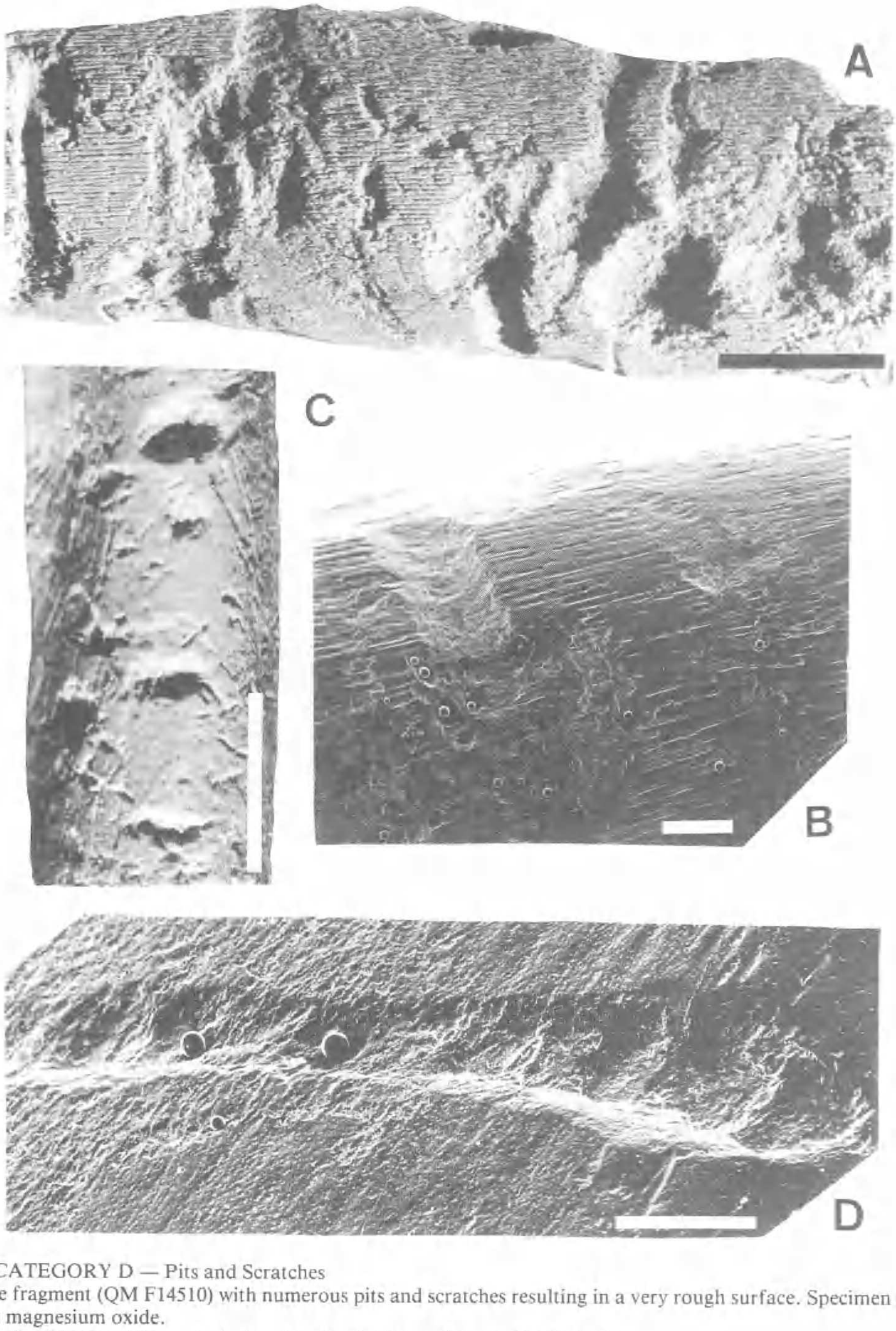

FIG. 7. CATEGORY D — Pits and Scratches

A Bone fragment (QM F14510) with numerous pits and scratches resulting in a very rough surface. Specimen coated with magnesium oxide.

B Scanning Electron Micrograph showing detail of scratches on QM F14510.

C Fifth metatarsal (QM F14509) of a small macropod showing pits and scratches. Specimen coated with magnesium oxide.

D Scanning Electron Micrograph of scratch mark showing distinct transverse basal corrugations (QM F14513).

Scale: A and C Scale Bar = 5 mm. B and D Scale Bar = 1 mm.

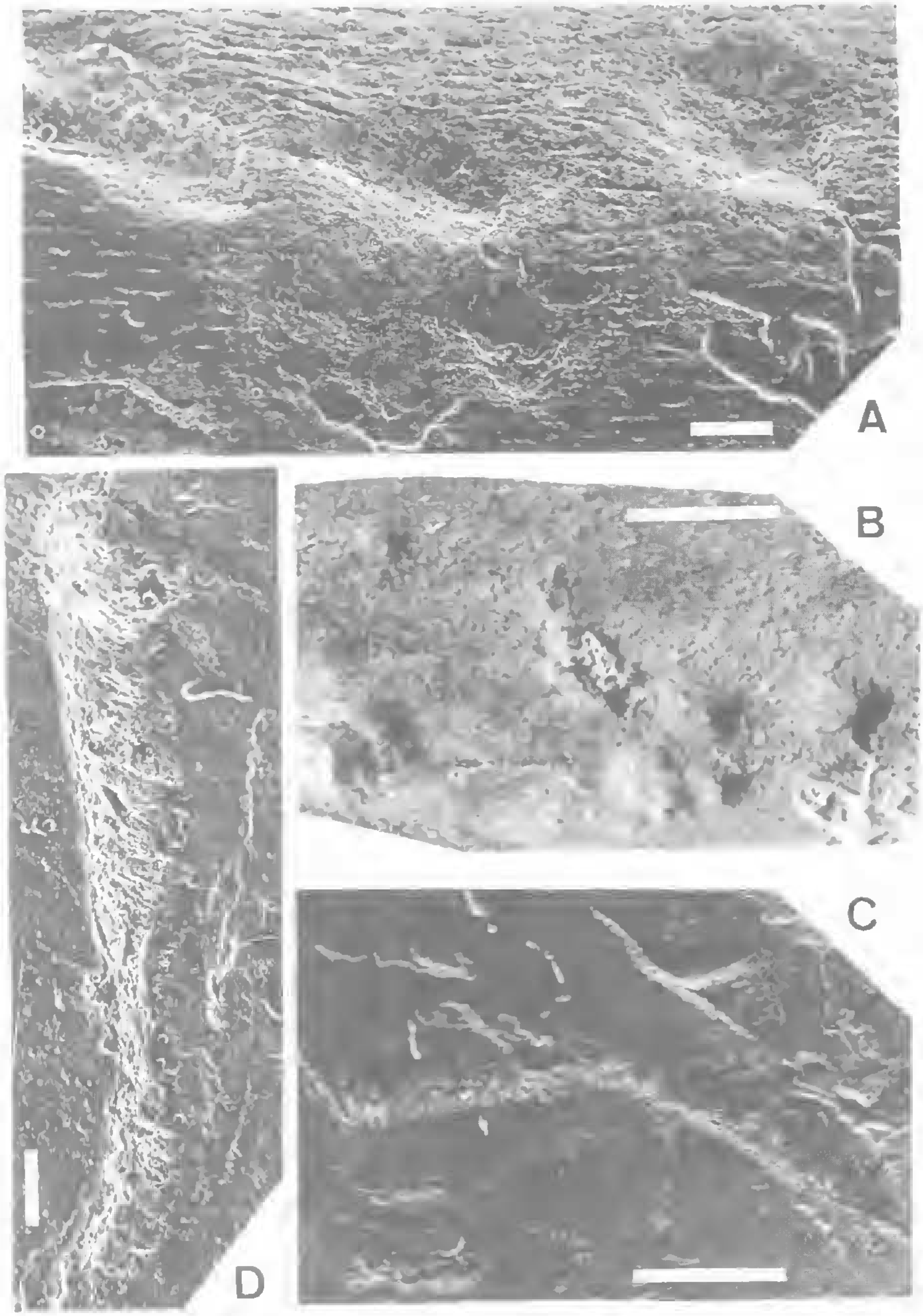

FIG. 8. CATEGORY D — Pits and Scratches
A Scanning Electron Micrograph of bone fragment (QM F14511) showing pit marks. The rough base in the pit at upper left is caused by an encrustation of calcium carbonate. This is also visible in the centre of photograph 8B.
B Bone fragment (QM F14511) showing pit marks.
C Bone fragment (QM F14514) with a boomerang shaped scratch mark. Note the round tooth impact point at the broad end of mark.
D Scanning Electron Micrograph showing initial portion of the boomerang shaped mark in 8C (QM F14514).
Scale: B and C Scale Bar = 5 mm. A and D Scale Bar = 1 mm.

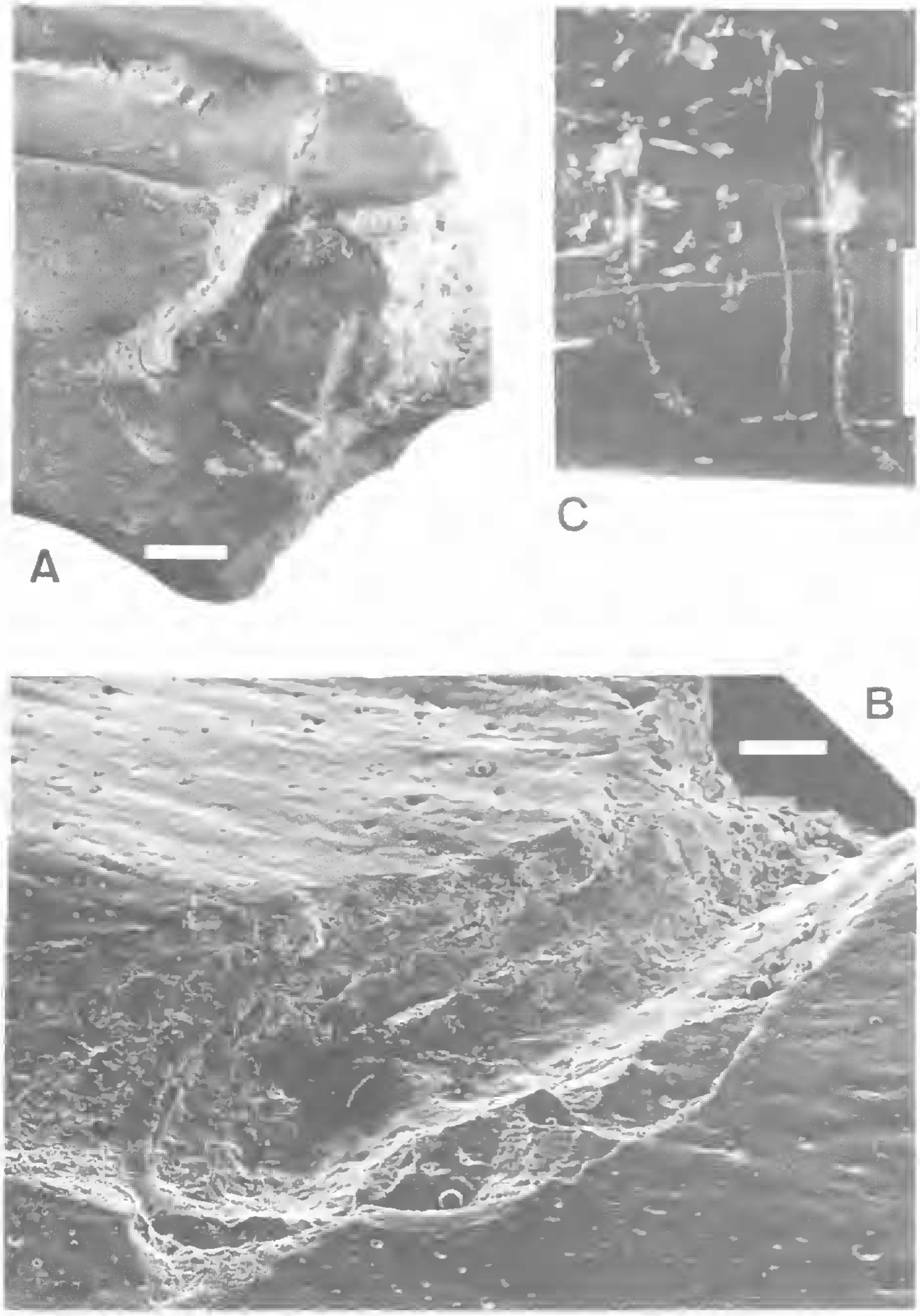

FIG. 9. CATEGORY E — Large Deep Scratches
A Caudal vertebra (QM F14515) of a large macropod with one end removed by carnivores. Note the scratch of exceptional size and depth.
B Scanning Electron Micrograph of the large deep scratch on QM F14515.
CATEGORY F — Fine Scratches Tapering to Each End
C Three scratches tapering to each end on tibia shaft (QM F14516). Distinct basal corrugations are visible.
Scale: A and C Scale Bar = 5 mm. B Scale Bar = 1 mm.

into the underlying spongy bone on specimen QM F14517. The surrounding compact bone is fractured and partially depressed (Fig. 10A); a fourth mark has depressed, but not fully punctured, the compact bone. These punctures appear to be similar to punctures assigned to a carnivore about the size of *Sarcophilus* by Archer *et al.* (1980, fig. 6). Several pits and scratches assignable to Category (D) are also present.

(H) LARGE OVAL PUNCTURES
Large oval punctures 14 mm long X 7 mm wide are present on three specimens. The compact bone has been depressed into the underlying cancellous bone and is still visible at the base of the tooth mark. Depth is in the range 5-9 mm (Fig. 10B). In all cases the long axis of the mark runs parallel to the long axis of the bone in which it is imprinted.

One specimen, QM F14519, shows small pits on the reverse side partially obscured by carbonate encrustation. Numerous marks assignable to Category (B) are visible on other parts of this specimen.

(I) SPONGY BONE REMOVAL WITH DEPRESSED PUNCTURES: FURROWING
The distal portion of a femur, QM F14520, has large areas of the articular surfaces removed. Included in these areas are the remnants of at least five depressed punctures 5-8 mm in diameter (Fig. 11). The remaining articular surface has one depressed puncture 3.5 mm diameter and 1.5 mm deep. A large, compressed oval fracture 10 mm X 6 mm is present at the base of the articular surface; depth is approximately 1 mm. This specimen is partly weathered, but the damage noted is undoubtedly primarily due to carnivores. Similar damage was referred to as furrowing by Haynes (1983).

(J) RAGGED EDGES AND HOLLOW-BACKED FLAKES
Many specimens have ragged edges which show small (4-5 mm) concave depressions where carnivore or scavenger gnawing has systematically removed the bone edge (Fig. 12A,B). Each concave depression represents the impact point of a tooth cusp. Some specimens also show depressions on bone edges in which the bite has removed a large flake from the back of the specimen (Fig. 12C,D). This category of tooth marks is unlikely to be assignable to any particular carnivore or scavenger.

The noted specimens also show tooth marks assignable to Categories (B), (D) and (F), which superficially resemble each other, especially in specimens that are partially weathered. It is only when non-weathered specimens are examined under magnification that the differences in profile can be fully appreciated.

FEEDING TRIAL

A *Sarcophilus* feeding trial was undertaken at the Lone Pine Koala Sanctuary, Brisbane. The animal selected for the feeding trial was a healthy mature male with an estimated age of six years. It was housed in a 6 by 6 m concrete and rock walled pen with a natural earth floor and shade trees. The captive animal's normal diet was rotationally selected from raw beef, commercial greyhound pellets, dead rats and chickens (P. Douglas, pers. comm.).

Because macropods form part of the natural diet of Tasmanian devils, and because a large percentage of bones found in the fossil sites under study are from medium (*Macropus siva*) and large (*Macropus titan* and *Protemnodon anak*) macropods, two articulated hind legs of a red-necked wallaby (*Macropus rufogriseus*) were used in this feeding trial. Test bones were largely stripped of meat and hide at the request of sanctuary staff to reduce the risk of introducing internal parasites. Care was taken not to mark the bones in this process. Phalanges were removed with the hide and were not presented for feeding.

Bones were placed in the pen at approximately 5 pm and removed at about 7.30 am the following day. The retrieved bones were boiled in enzyme detergent solution (Bio-Ad^{TM}) to remove all remaining flesh and tendons, and then dried and examined for tooth marks.

Three bones (a femur and two metatarsals) had been consumed; others had some areas consumed and showed evidence of tooth marks. A detailed summary of damage is presented in Appendix 2.

DESCRIPTION OF TOOTH MARKS

The marks produced by *Sarcophilus harrisii* on the wallaby bones fall into five distinct categories.

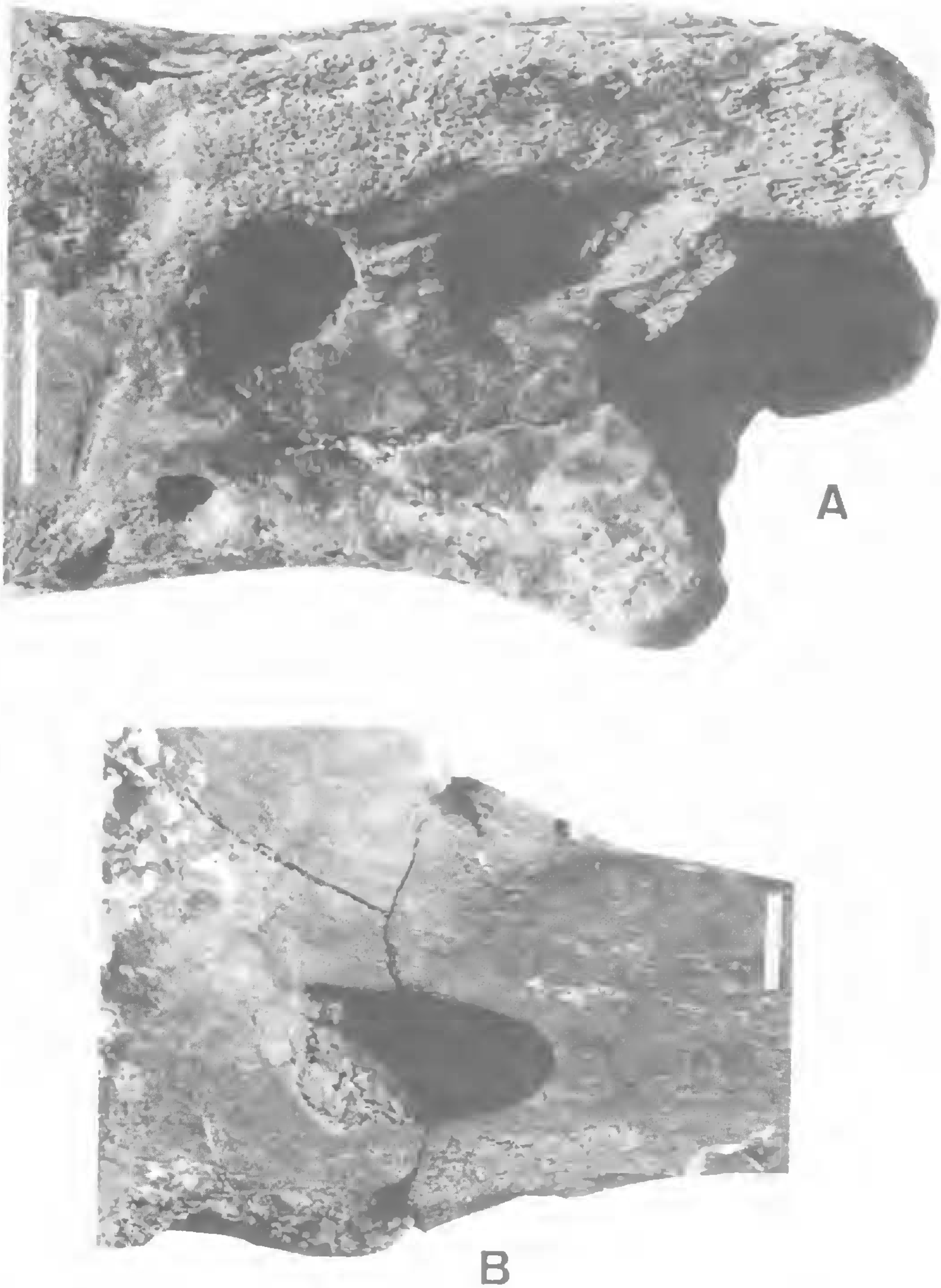

FIG. 10. CATEGORY G — Round Punctures
A Bone section (QM F14517) showing small round punctures. The small hole at lower left is a foramen.
CATEGORY H — Large Oval Punctures
B Partial macropod pelvis (QM F14519) showing a large oval puncture in the pubis.
Scale: A and B Scale Bar = 5 mm.

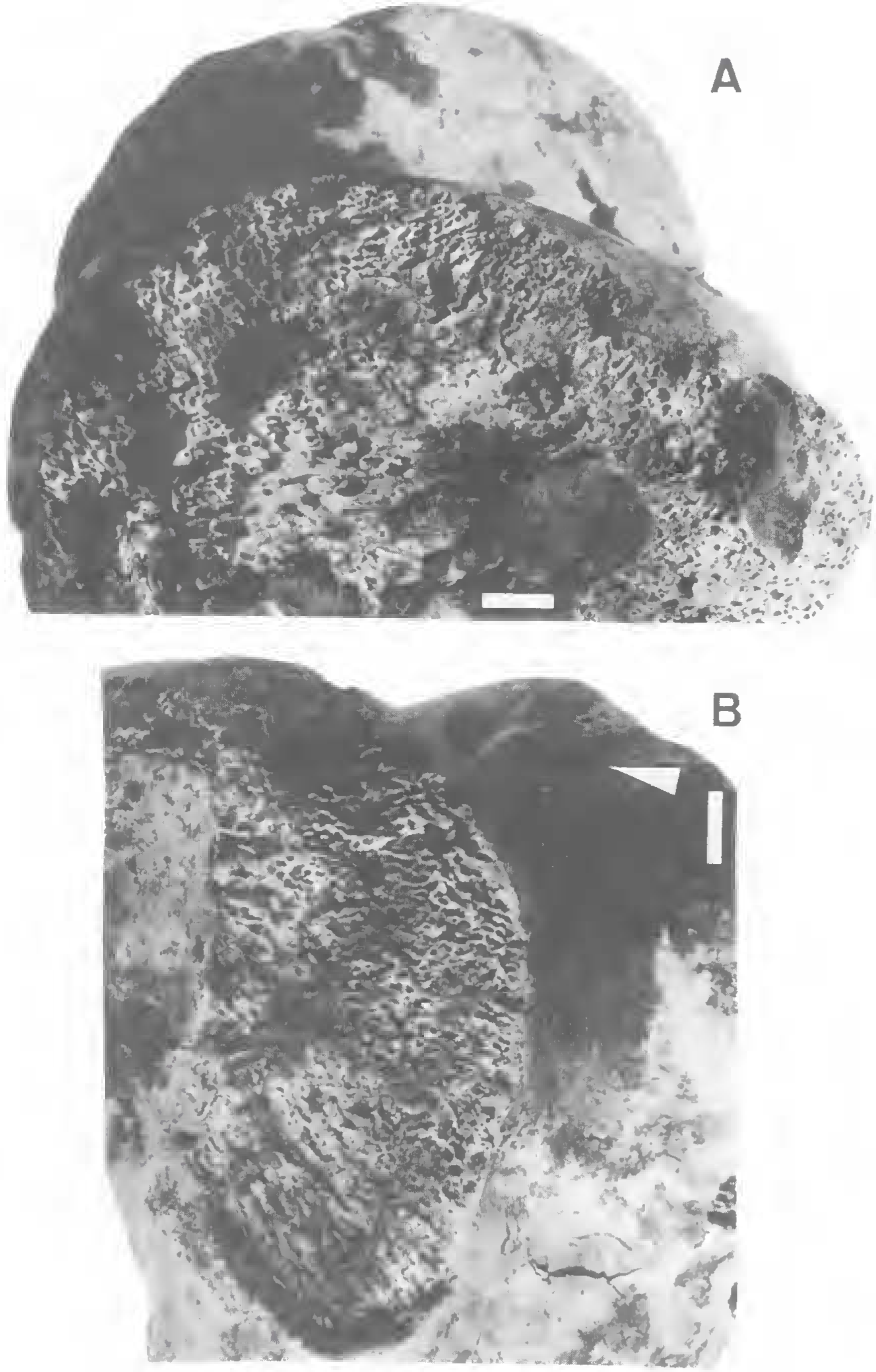

FIG. 11. CATEGORY 1 — Spongy Bone Removal with Depressed Punctures
A Distal femur (QM F14520) showing removal of articular surfaces and several depressed punctures.
B Another view of QM F14520 showing similar damage plus a compressed fracture at lower right and small round puncture at upper right (Arrowed).
Scale: A and B Scale Bar = 5 mm.

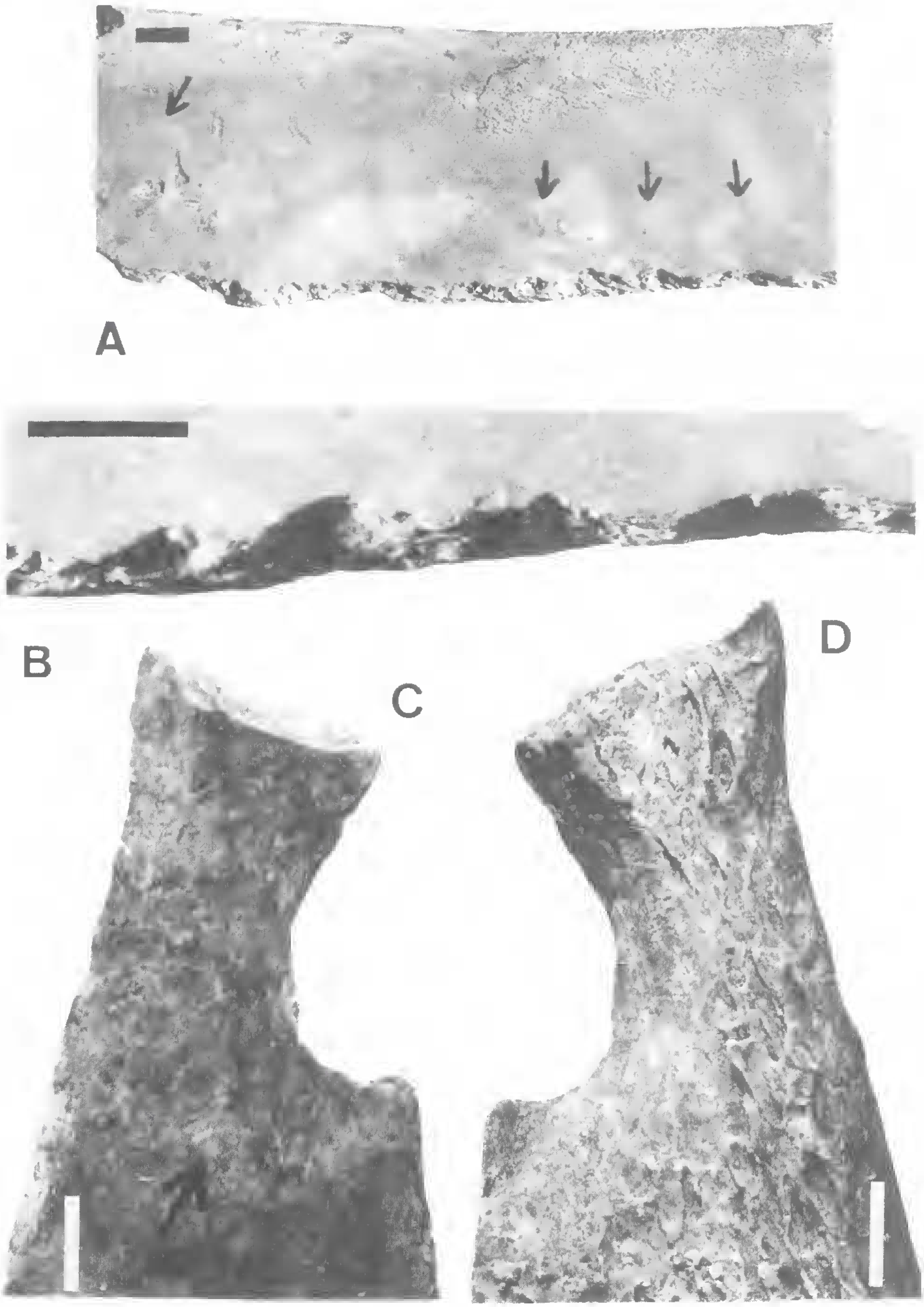

FIG. 12. CATEGORY J — Ragged Edges and Hollow Backed Flakes
A Tibia fragment (QM F14521) showing a ragged edge produced by carnivore gnawing.
B Enlargement of gnawed edge on QM F14521.
C Obverse view of bone fragment (QM F14523) with a concave edge where a bite has removed a flake of bone.
D Reverse view of QM F14523 showing the hollow back produced by the bite.
Scale: All Scale Bars = 5 mm.

(1) VERY SHALLOW SCRATCHES: These are particularly noticeable on the proximal end of the tibia, adjacent to areas of heavier tooth marks; some are also present on the distal end of the femur. These scratches commence at a maximum width of 0.3-1 mm and taper to disappear entirely. Length varies between 3 mm and 20 mm, but only occasionally do they exceed 10 mm (Fig.13). They are extremely shallow, barely breaking the surface of the compact bone. These marks may be caused by incisor teeth in removing small areas of muscle and tendon, although some may be claw marks produced when the bones are held in the front paws during feeding. Solomon (pers. comm., 1987) has observed this type of feeding behaviour by devils. It is doubtful that such shallow marks would survive to be visible in fossil specimens, particularly those from fluviatile deposits.

(2) PITS AND SCRATCHES: Deeper pits and scratches are present on all chewed bones and are particularly noticeable on opposing surfaces of the femur and metatarsals. Pits are round to oval with a maximum diameter of 2 mm; most are 1 mm — 1.5 mm. Depth ranges up to a maximum of 1 mm (Fig. 14). Occasional pits show a concentric double crater effect (Fig. 15A; see Solomon, 1985). Scratches are elongated round bottomed marks with a maximum length of 5 mm and maximum width of 1.5 mm. Smaller and more shallow scratches are nearly parallel while larger and deeper scratches taper slightly and become more shallow along their length (Figs 14, 15). Scratches often show basal corrugations at right angles to the long axis of the mark where a tooth has broken through successive layers of bone tissue (Fig. 15). These pits and scratches are often associated in large numbers on opposing bone surfaces (femur and metatarsals) producing a very rough appearance (Fig. 14). Both pits and scratches appear to be produced by carnassial teeth as these were used to break the bone into pieces small enough to be swallowed. These marks should be easily visible in fossil material, with the exception of specimens which are severely weathered or abraded.

(3) LARGE PUNCTURES WITH SPONGY BONE REMOVAL: FURROWING. Part of the articular surface and underlying spongy bone have been removed from the distal end of the femur. Impressed in this region are large punctures of oval or triangular outline with maximum width of 8 mm and maximum depth of 5 mm (Fig. 16A). These marks appear to be from carnassial and possibly canine teeth. They appear larger and deeper simply because of the lesser resistance offered by the spongy bone. Damage of this type was referred to as furrowing by Haynes (1983), and it should be easily visible in well-preserved fossil material.

(4) SEMICIRCULAR MARK: The broken end of one fibula shows a semi-circular mark perpendicular to the long axis of the bone; here a round tooth or tooth cusp has broken through the bone, severing it into two pieces (Fig. 16B). Despite being clearly recorded, this mark is unlikely to be diagnostic.

(5) DEEP LONGITUDINAL "V". A deep "V" parallel to the long axis of the bone is impressed in the chewed proximal end of the tibia (Figs 16C, D). The end of the "V" has the compact bone depressed downwards into the underlying spongy bone. The reverse side of the bone shows remnants of two similar marks, one being the counterpart of the mark described above. These depressed areas, which have a width of 5 mm — 6 mm, appear to be made by canine teeth and should easily be preserved in fossil material.

DISCUSSION

It is conceivable that the tooth marks and amount of damage observed may not be entirely representative for *Sarcophilus*. Additional feedings and field studies need to be conducted, using other portions of carcasses and whole carcasses. As much of the fossil material found in southeastern Queensland Pleistocene sites is from larger macropods, trials using larger macropods would be desirable.

Feeding competition by numbers of animals may change the intensity of marks and damage. Guiler (1983) noted up to twelve animals feeding on and squabbling over a carcass. This may result in complete consumption of the carcass. The effects of such behaviour could not be investigated here because too few animals were available.

The marked bones discussed in this paper are all derived from fluviatile deposits. Fluvial action will undoubtedly have an affect on any bones that find their way into such an environment. The nature and extent of that damage and, more importantly, its

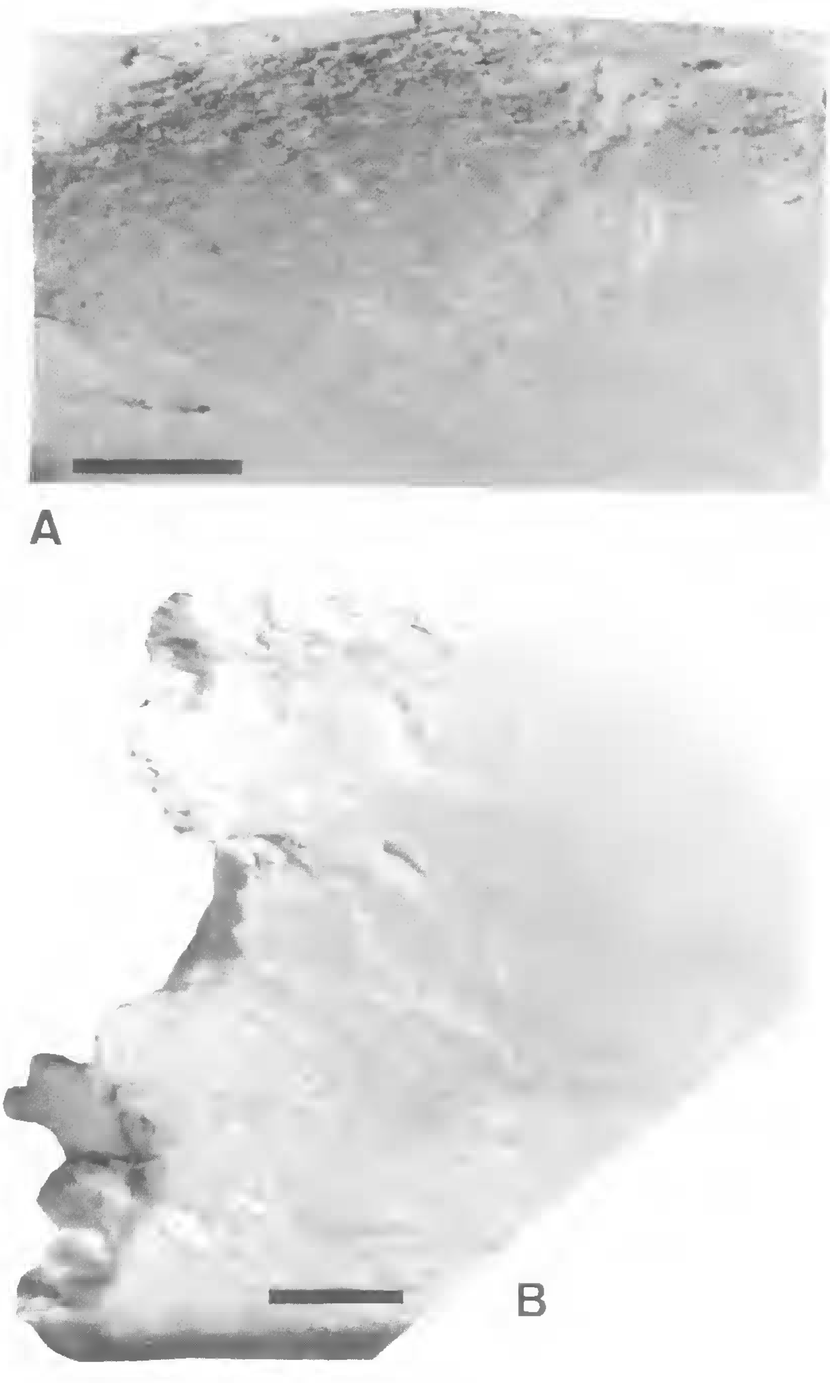

FIG. 13. CATEGORY I — Very Shallow Scratches (Feeding Trial)
A Wallaby proximal tibia (QM JM6533) showing very shallow scratches; one being of extreme length.
B Wallaby tibia (QM JM6527) with proximal end consumed. Some very shallow scratches are prsent along with much deeper pits and scratches.
Scale: A and B Scale Bar = 5 mm.

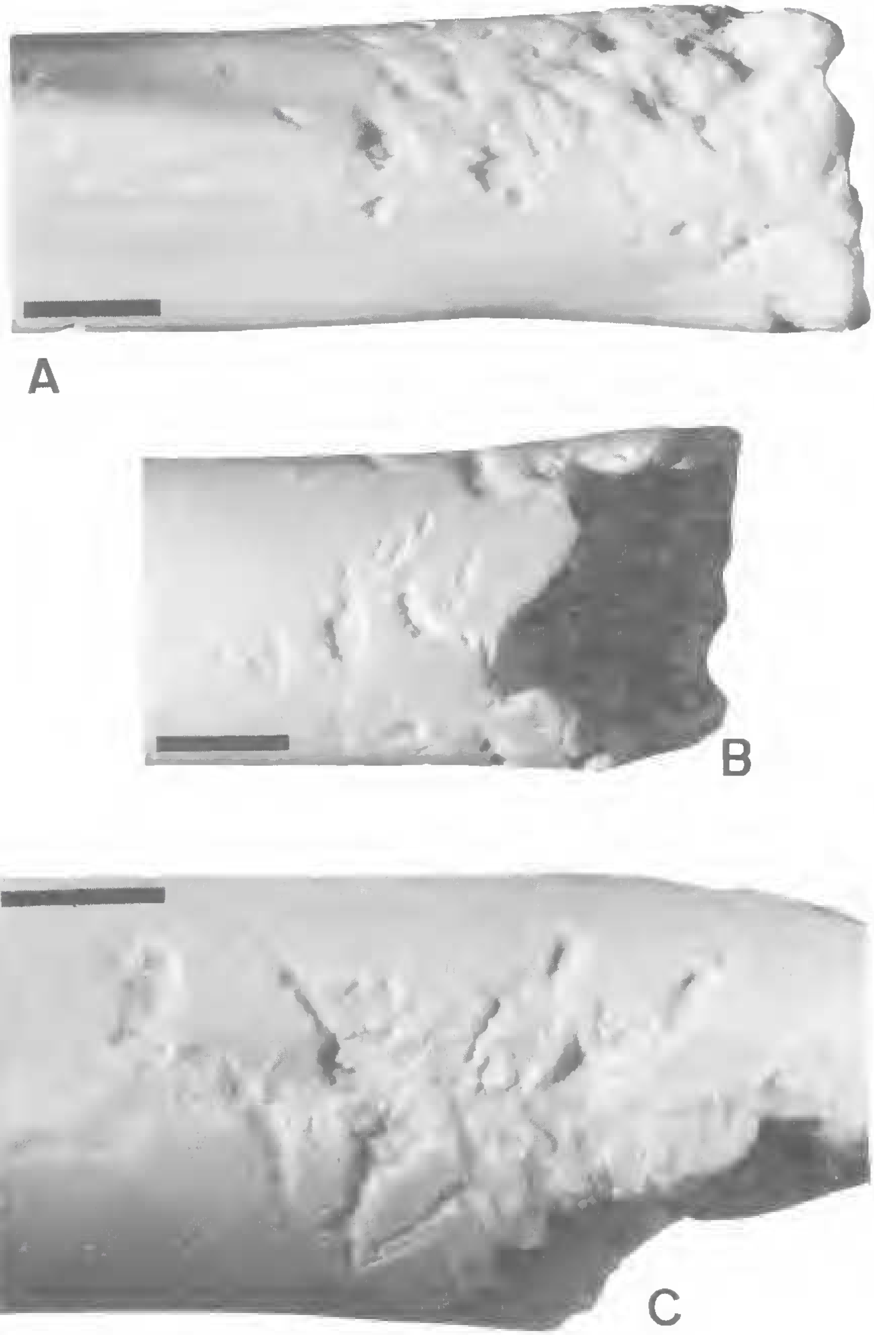

FIG. 14. CATEGORY II — Pits and Scratches (Feeding Trial)
A Wallaby fourth metartarsal (QM JM6530) with distal end removed by chewing. Adjacent areas show numerous pits and scratches producing a very rough surface.
B Reverse side of metatarsal (QM JM6530) shown in 14A.
C Shaft of wallaby femur (QM JM6532) with proximal end removed by chewing. Numerous pits and scratches producing a very rough surface.
Scale: A, B and C Scale bar = 5 mm.

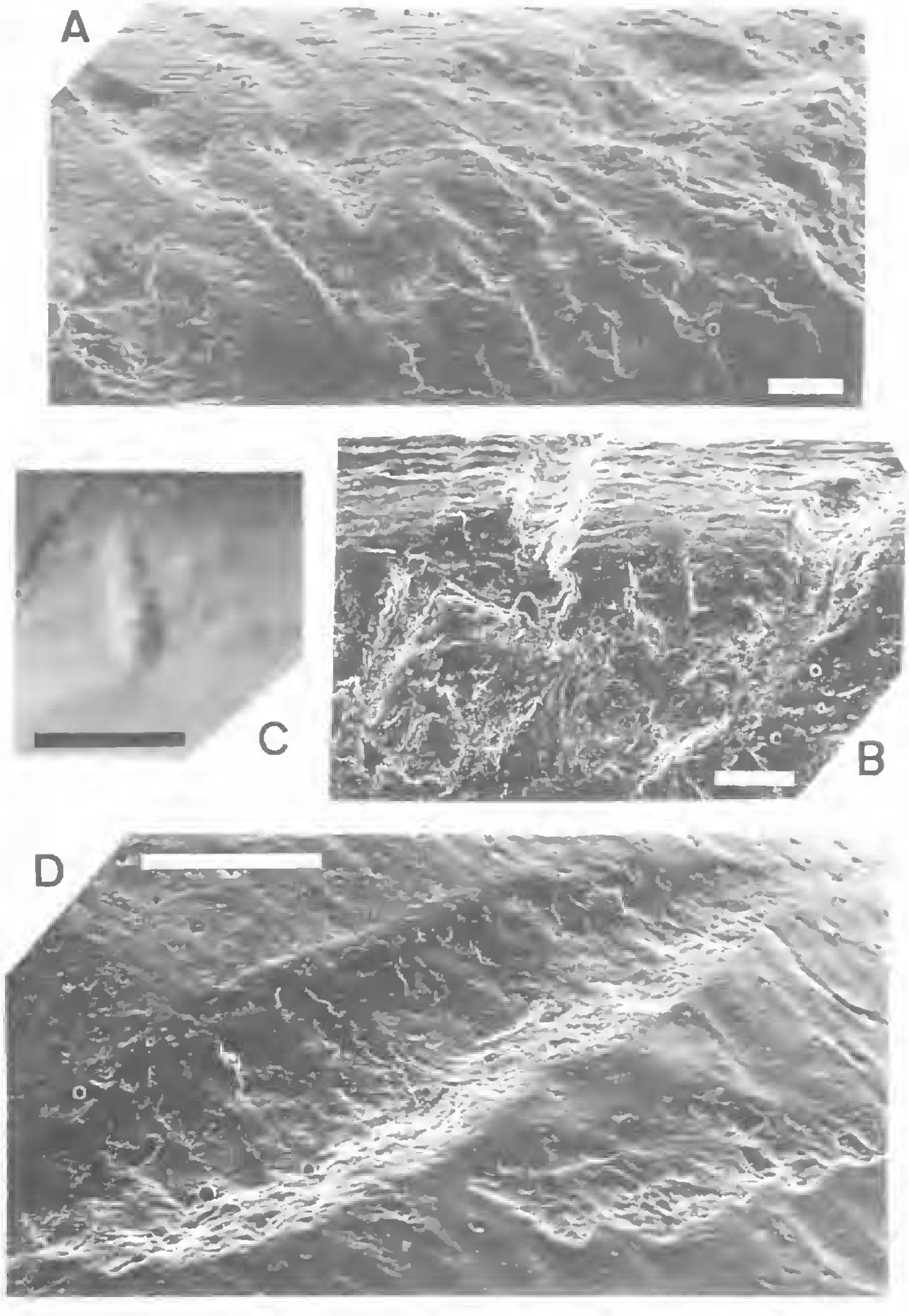

FIG. 15. CATEGORY II — Pits and Scratches (Feeding Trial)

A Scanning Electron Micrograph of distal fourth metatarsal (QM JM6530) shown in Fig. 14A. Note concentric double crater at top right.

B Scanning Electron Micrograph of proximal femur (QM JM6532) shown in Fig. 14C.

C Large scratch mark on wallaby femur (QM JM6532) showing distinct transverse basal corrugations.

D Scanning Electron Micrograph of large scratch mark on wallaby femur (QM JM6532) shown in Fig. 15C to show detail of the transverse corrugations.

Scale: A, B and D Scale Bar = 1 mm. C Scale Bar = 5 mm.

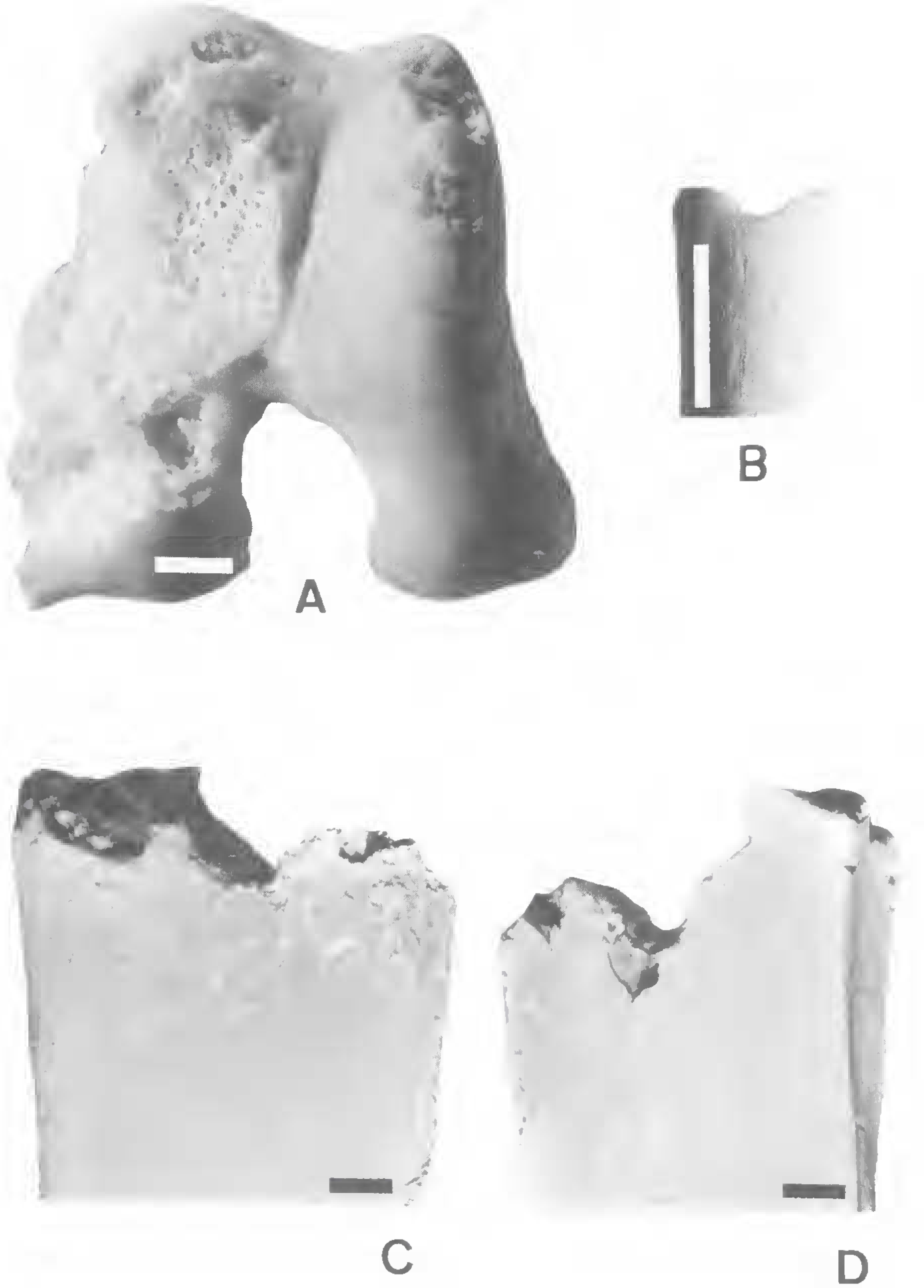

FIG. 16. CATEGORY III — Large punctures with Spongy Bone Removal (Feeding Trial)
A Distal femur (QM JM6532) showing where the articular surface and underlying spongy bone have been removed. Several large punctures are visible.
CATEGORY IV
B Proximal fibula (QM JM6528) showing semicircular tooth mark where the bone was bitten into two pieces.
CATEGORY V — Deep Longitudinal "V" (Feeding Trial)
C Reverse view of proximal tibia (QM JM6527) showing remnants of two deep "V" shaped marks.
D Obverse view of proximal tibia (QM JM6527) showing deep "V" shaped mark.
Scale: A, B, C and D Scale bars = 5 mm.

ability to mimic tooth marks is of importance to this paper. Shipman and Rose (1983a) have shown that sedimentary abrasion tends to obliterate marks on bone and only occasionally produces marks that mimic carnivore tooth scratches.

Marks produced by contact with rocks need to be considered. The biggest rocks in the measured section are 5-7 cm in diameter, and, these occur only in the lowest exposed level. Most of these large pieces are calcareous and well-rounded, with few sharp projections. Some hard, well-rounded rocks occur in the very lowest levels of locality 1, but only a small number of bones was recovered from this level. The remainder of the matrix is composed of fine sandy alluvium with patches of small pebbles. In localities (2) and (3), marked bones are found both in the finer sediments and in the underlying nodular areas. A very high proportion of the marks derived from the nodular areas are abraded to a point where many of the features of the marks are obliterated and are often not able to be assigned to a particular category with confidence. Specimens with this degree of abrasion are much rarer in the finer sediments.

If these marks were produced by contact with stones during transport and deposition, the greatest concentration of unabraded marks would be expected to occur on bones in the stony areas. However, the reverse is true, with these bones having most marks heavily abraded. It would appear, therefore, that fluvial action is obliterating rather than producing the marks considered here.

The object of the feeding trial was to establish the appearance of a normal range of tooth marks on bone fed to *Sarcophilus harrisii*. These marks were then compared with a collection of tooth marks on fossil bones to see if *Sarcophilus* damage could be recognised in the fossil sample. Five categories (named and numbered 1-5) of tooth marks were recognised on bones fed to *Sarcophilus* at Lone Pine Koala Sanctuary, whilst ten categories (named and designated A-J) were recognised in the fossil material.

A distinct overlap is present within the modern and fossil tooth marks. The most numerous tooth marks in the feeding trial are pits and scratches (Category 2). Similar pits and scratches (Category D) are among the most common tooth marks in the fossil material. The two categories are clearly similar in the size and shape of the marks. In both cases the tooth marks tend to be so densely grouped as to give the bone a very roughened surface, particularly near the extremities. This is especially noticeable in both fossil and trial metatarsals.

Specimens are present from both the fossils and feeding trial where areas of articular surface and the underlying spongy bone have been removed (Categories 3 and I). Both show large punctures up to 8 mm diameter where teeth have penetrated the spongy bone. Both specimens are distal portions of femora, a fact which may be coincidental or may show a preferential feeding habit. Although the fossil specimen is partly weathered there is clear overlap between these two classes of marks.

The round punctures (Category G) are clearly similar to those attributed to a carnivore about the size of *Sarcophilus* by Archer *et al.* (1980). They are not exactly duplicated in the feeding trial but might easily be produced by the teeth of *Sarcophilus*. These marks are not considered to be of diagnostic value.

There is great similarity between the tooth marks produced by *Sarcophilus harrisii* in feeding trials and some categories of tooth marks found on fossil bones from Pleistocene sites in southeastern Queensland. *Sarcophilus* is well represented by dental elements in these sites. Thus it seems likely that *Sarcophilus* was one of the principal carnivores present during the Pleistocene in southeastern Queensland and that its presence may be detected by the examination of tooth marked bones.

Some tooth marks in the fossil sample are clearly not the work of *Sarcophilus*. Of these, some may be attributed to rodents and *Thylacoleo*, whilst others are of uncertain origin. Dingos have not been considered as a possible source of tooth marks because their skeletal remains are unknown from the fossil beds considered here. Moreover the earliest skeletal remains of a dingo come from Madura Cave, Western Australia, and are dated at 3450 ± 95 B.P. (ANU807) (Solomon & David, 1987); the King Creek beds are at least 20,000 years older (minimum age 23,600 ± 600 B.P.)

Looking at faunal lists we would expect to find tooth mark evidence of other major Pleistocene predators like thylacines, crocodiles and *Megalania*. However, because of the voracious feeding habits of crocodiles and Komodo Dragons (the closest comparable varanid to *Megalania*), along with the ability to substantially digest bone, tooth mark evidence for these carnivores may be difficult to locate (see Auffenberg (1972) for a discussion of the feeding habits of Komodo Dragons).

These unidentified tooth marks are to be the basis of further studies.

ACKNOWLEDGEMENTS

Many people have helped during the course of this project. Firstly, thanks go to my wife Diane for her patience and for typing the various drafts of this manuscript. Scanning electron microscopy was carried out by Rob Jupp and Bill Young (Department of Oral Biology and Oral Surgery, University of Queensland) with the cooperation of the Electron Microscope Centre, University of Queensland. Su Solomon, Andrew Rozefelds, Mary Wade, Peter Hiscock and Susan Turner made valued comment on various drafts of the manuscript. Alan Bartholomai, Ralph Molnar, Steve van Dyck, Rod Wells, David Horton, Mike Archer, Bruce Runnegar and the late Edmund Gill commented on various specimens. The *Sarcophilus* feeding trial was carried out at Lone Pine Koala Sanctuary, Brisbane with the kind co-operation and help of Mr Peter Douglas. Mr Peter Pearce (Soil and Water Conservation Branch, Department of Primary Industries, Clifton) helped measure the stratigraphic section of King Creek. Photography was undertaken by Bruce Cowell, Queensland Museum, and the final manuscript was typed by Peta Woodgate. This work was supported by an honorary research fellowship of the Queensland Museum.

LITERATURE CITED

ARCHER, M., CRAWFORD, I. AND MERRILEES, D. 1980. Incisons, breakages and charring, some probably man made, in fossil bones from Mammoth Cave, Western Australia. *Alcheringa* 4: 115–31.

CLAYTON, G. AND HAND, S. 1984. A checklist of Australian Fossil Mammals. p. 1027–87 *In* Archer, M. and Clayton, G. (Eds) 'Vertebrate Zoogeography and Evolution in Australia'. (Hesperian Press: Perth).

AUFFENBERG, W. 1972. Komodo Dragons. *Natural History* **81**(4): 52–9.

BAIRD, R. 1985. Tasmanian Native Hen *Gallinula mortierii*. The first late Pleistocene record from Queensland. *The Emu* **86**(2): 121–2.

BARTHOLOMAI, A., 1976. Notes on the Fossiliferous Pleistocene Fluviatile Deposits of the Eastern Darling Downs. *Bureau of Mineral Resources, Bulletin* **166**: 153–4.

BEHRENSMEYER, A.K. 1978. Taphonomic and Ecologic information from Bone Weathering. *Paleobiology* 4(2): 150–62.

DE VIS, C.W. 1900. Bones and Diet of *Thylacoleo*. *Annals of the Queensland Museum* **5**: 7–11.

DOUGLAS, A.M., KENDRICK, G.W. AND MERRILEES, D. 1966. A fossil bone deposit near Perth, Western Australia, interpreted as a carnivore's den after feeding tests on living *Sarcophilus* (Marsupialia, Dasyuridae). *Journal and Proceedings of the Royal Society of Western Australia* **49**: 88–90.

GILL, E.D. 1978. Geology of the Late Pleistocene Talgai Cranium from S.E. Queensland, Australia. *Archaeology and Physical Anthropology in Oceania* **13**: 177–97.

GUILER, E.R., 1983. Tasmanian Devil. p. 27-8 *In* Strahan, R. (Ed) 'The Australian Museum Complete Book of Australian Mammals'. (Angus and Robertson Publishers: Sydney).

HANSON, C.B. 1980. Fluvial Taphonomic Processes: Models and Experiments. P. 156-81 *In* Behrensmeyer, A. and Hill, A. (Eds.) 'Fossils in the Making'. (University of Chicago Press: Chicago).

HAYNES, G., 1980. Evidence of Carnivore Gnawing on Pleistocene and Recent Mammalian Bones. *Paleobiology* **6**(3): 341–51.

1983. A guide to differentiating Mammalian Carnivore taxa, responsible for gnaw damage to herbivore limb bones. *Paleobiology* **9**(2): 164–72.

HORTON, D.R. and WRIGHT, R.V.S. 1981. Cuts on Lancefield Bones:Carnivorous *Thylacoleo*, not Humans, the cause. *Archaeology in Oceania* **16**: 73–80.

MOLNAR, R.E. 1982. A Catalogue of Fossil Amphibians and Reptiles in Australia. *Mem. Qd Mus.* **20**(3): 613–33.

POTTS, R. AND SHIPMAN, P. 1981. Cuts made by Stone Tools on Bones from Olduvai Gorge, Tanzania. *Nature* **291**: 577–80.

ROSE, J. 1983. A Replication Technique for Scanning Electron Microscopy: Applications for Anthropologists. *American Journal of Physical Anthropology* **66**: 255–61.

RUNNEGAR, B. 1983. A *Diprotodon* ulna chewed by the Marsupial Lion, *Thylacoleo carnifex*. *Alcheringa* **7**: 23–5.

SHIPMAN, P. AND ROSE, J. 1983(a). Early Homonid hunting, butchering and carcass processing behaviour: approaches to the fossil record. *Journal of Anthropology and Archaeology* **2**: 57-98.

AND ROSE, J. 1983(b). Evidence of butchering and homonid activities at Torralba and Ambrona: an evaluation using microscopic techniques. *Journal of Archaeological Sciences* **10**: 465–74.

AND ROSE, J. 1984. Cutmark mimics on modern and fossil bovid bones. *Current Anthropology* **25**: 116–7.

SOLOMON, S., 1985. People and other Aggravations. Taphonomic research in Australia. Bachelor of Arts thesis, Department of Prehistory and Archaeology, University of New England, Armidale, New South Wales (Unpublished).

AND DAVID, B. (in press). Middle range theory and actualistic studies: Bones and dingoes in Australian Archaeology. "Taphonomy of Bones Conference", University of New England, Armidale, 21-22 February, 1987.

SPENCER, B. AND WALCOTT, F.G.S., 1911. The origin of cuts on Bones of Australian Extinct Marsupials. *Proceedings of the Royal Society of Victoria* **24**(1): 92–123.

Wood, W.R. and Johnson, D.L. 1978. A Survey of Disturbance Processes in Archaeological Site Formation. P. 539-605 *In* Schiffen, M.A. (Ed.) 'Advances in Archaeological Method and Theory', vol. 1. (Academic Press: New York).

Woods, J.T., 1960. Fossiliferous fluviatile and cave deposits. *Journal of the Geological Society of Australia* 7: 393-403.

APPENDIX 1

REFERRED FOSSIL SPECIMENS

(A) ROUND BOTTOMED SCRATCHES WITH ANCHOR POINTS

QM F14504: from locality (1) (King Creek). Central fragment of a rib of a large macropod which measures 165 mm in length X 12 mm average diameter.

(B) BLADE LIKE IMPRESSIONS

QM F14505: from locality (5) (Budgee Creek). Proximal portion of a rib of a large macropod? showing six bite marks. Length 165 mm; Average Diameter 12 mm.

QM F14506: from locality (2) (King Creek). Central fragment of large macropod pelvis showing three bite marks. Length 85 mm; Width 55 mm.

QM F14507: from locality (3) (King Creek). Unidentified large radius missing distal end (chewed off). Length 365 mm; Average Diameter 25 mm. Numerous bite marks each end.

(C) CRESCENT SHAPED MARKS

QM F14508: from locality (1) (King Creek). Fragment of a long bone showing three crescent shaped marks. Length 113 mm; Width 23 mm.

(D) PITS AND SCRATCHES

QM F14509: from locality (3) (King Creek). Fifth metatarsal of a small macropod, missing distal extremity. Numerous pits and scratches over much of bone. Length 77 mm; Width 10 mm.

QM F14510: from locality (1) (King Creek). Bone fragment with numerous pits and scratches. Length 51 mm; Width 10 mm.

QM F14511: from locality (1) (King Creek). Long bone fragment with six pit marks. Length 187 mm; Width 28 mm.

QM F14512: from locality (1) (King Creek). Long bone fragment with six scratch marks, with corrugated bases, arranged in boomerang shape. Length 63 mm; Width 19 mm.

QM F14513: from locality (3) (King Creek). Bone fragment with transverse scratches with distinctly corrugated bases. Length 208 mm; Width 15 mm.

QM F14514: from locality (1) (King Creek). Bone fragment with numerous scratches. One boomerang shaped mark shows distinct round impact point. Length 40 mm; Width 30 mm.

(E) LARGE DEEP SCRATCHES

QM F14515: from locality (1) (King Creek). Caudal vertebra of a large macropod with one end missing due to carnivores. Length 75 mm; Diameter 54 mm.

(F) FINE SCRATCHES TAPERED AT BOTH ENDS

QM F14516: from locality (1) (King Creek). Shaft of tibia from large macropod, both ends showing tooth marks. Length 345 mm; Width 48 mm.

(G) ROUND PUNCTURES

QM F14517: from locality (3) (King Creek). Bone section with small round punctures. Length 31 mm; Width 17mm.

(H) LARGE OVAL PUNCTURES

QM F14518: from locality (1) (King Creek). Bone fragment with one large oval puncture. Length 110 mm; Width 32 mm.

QM F14519: from locality (1) (King Creek). Central portion of the pelvis of a very large macropod with one large oval puncture on the pubis. Length 350 mm.

(I) SPONGY BONE REMOVAL WITH DEPRESSED PUNCTURES: FURROWING

QM F14520: from locality (3) (King Creek). Distal portion of femur (?macropod). Length 70 mm; Width 65 mm.

(J) RAGGED EDGES AND HOLLOW BACKED FLAKES

QM F14521: from locality (1) (King Creek). Fragment of shaft of large tibia (?macropod). Length 243 mm; Width 30 mm.

QM F14522: from locality (1) (King Creek). Shaft of tibia from large macropod. Length 345 mm; Width 48 mm.

QM F14523: from locality (1) (King Creek). Bone fragment with semicircular flake removed leaving a hollow back. Length 115 mm; Width 38 mm.

APPENDIX 2

SUMMARY OF DAMAGE TO BONES FROM FEEDING TRIAL

LEG 1

Femur: This was apparently consumed as no portion of the bone was returned.

Tibia (QM JM6527): 2.5 cm of the proximal end was consumed leaving a rather jagged edge on the remainder. The adjacent 4 cm showed tooth marks ranging from very shallow scratches to more deeply impressed pits and scratches. A large depressed fracture is present at the edge of the proximal end.

Fibula (QM JM6528): 2.5 cm of the proximal end was consumed. The fractured end retains a single furrow perpendicular to the long axis of the bone where a bite has severed the consumed end. The adjacent 5 cm of the bone show occasional small pits and scratches.

Calcaneum (QM JM6529): Returned intact, but with several small pits and scratches present.

Metatarsals: Metatarsals 2 and 3 were not returned. The distal 2 cm of metatarsal 4 (QM JM6530) and distal 1.5 cm of metatarsal 5 (QM JM6531) were consumed leaving jagged edges. The adjacent 1-2 cm show extensive areas of tooth marks made up of a series of pits and scratches. These are very closely spaced and leave the bone surface with an extremely rough texture.

LEG 2

Femur (QM JM6532): One third of the proximal end was consumed, leaving the end with a jagged outline. The adjacent 2 cm have areas of closely spaced pits and scratches leaving the bone with a very rough surface. Approximately one third of the distal articular surface and underlying spongy bone were consumed. Large depressed tooth marks are present in the remaining spongy bone. These appear to be from carnassial teeth.

Tibia (QM JM6533): Damage is slight and restricted to the proximal 5 cm of the bone. Small areas of spongy bone have been removed. Three large pits are present on the edge of the epiphysis. Adjacent areas of the shaft show long but very shallow scratches.

Fibula (QM JM6534): Several shallow scratches are present 3-4 cm from the distal end. Calcaneum (QM JM6535): No damage was evident. Metatarsals (QM JM6536): No damage was evident.